Clandestine ELOS/OTH RF Communications for Unmanned Underwater Vehicles

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Grant #: N000140110111

LONG-TERM GOAL

The long term goal of this research is to identify fundamental issues and required technological developments for small long range communications systems utilizing HF ground wave propagation that can be used in extended-line-of-sight and over-the-horizon (ELOS/OTH) communications. Because ELOS/OTH transmission over water requires HF frequencies to diffract beyond line-of-sight, the sizes of standard antennas such as quarter wave monopoles are too large for UUV operation. Therefore, a major focus of this effort is on the development of electrically small antennas.

OBJECTIVES

The objectives of this effort are to assess small antenna designs, fundamental mechanisms for radiation, tuning, and dissipation losses. A further object is to build and test a low power demonstration radio for bandwidth efficient HF communications.

APPROACH

Under previous ONR funding, an assessment was made about a variety of OTH communications techniques. An HF system is being constructed using the folded conical helix (FLEX) antenna, shown in Figure 1. A focus of this effort is to package this antenna in a form suitable for installation on a UUV. Another focus of this effort is the development of a small low-power radio that can provide sufficient data transmission rates for the desired ranges.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **Clandestine ELOS/OTH RF Communications for Unmanned Underwater Vehicles**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Applied Research Laboratories,,The University of Texas at Austin,,Austin,,TX, 78713**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

WORK COMPLETED

There were three major efforts that were pursued. The first was to develop an antenna and antenna deployment system that would be compatible with UUV operation, and be mechanically robust enough to withstand wave-slap when deployed. This antenna design is based on a previous design described in [1-3]. The second was to perform the design, fabrication, and test of an electronic pressure housing. The third item was to provide a radio for testing purposes. Originally the radio was expected to be a commercial radio and modem that would be packaged for the UUV in the pressure housing. However, the power consumption, low data rate, and poor form factor made this approach very difficult to implement. In addition, an opportunity arose to jointly develop a pc-based radio system for demonstration and testing. These radios have great flexibility in the modulation types, bandwidths, data rates, and receiver architectures; they also offer an opportunity to test the basic concepts to be implemented in the radio. Although the pc-based radio is too large and consumes too much power to be acceptable for the UUV, the fact that a number of the software and modulation concepts could be implemented and tested provided a basis from which the small radio development could be accelerated. Therefore, the high data rate radio developed this year is ahead of schedule by nearly a full year. The commercial radio system was not pursued.

Figure 1. HF radio, pressure housing, and retractable antenna assembly for UUV

Figure 2. Collapsible FLEX antenna shown in its deployed configuration

A motor-driven antenna deployment assembly and a pressure vessel was designed and fabricated. Significant effort was put into building a marine antenna. The antenna was orginally designed to be a solid cylinder, but was later modified to accomodate vehicle requirements. The antenna is extended and retracted on a leadscrew which provides stability and strength as well as a robust means for extending and retracting the antenna. Flotation was added as shown in Figure 1 to provide neutral buoyancy for the overall assembly. The antenna is shown in the retracted position.

In addition to this antenna, another antenna which could be collapsible was fabricated and tested. An early prototype is shown in Figure 2. Initial tests indicate that the antenna has a relative gain of about 5dB below the a reference quarter wave monopole. The protopype is made of aluminum and can compress to 50 percent of its neutral height. The spacers are used for testing purposes.

Radios and Testing. Two radio systems were built. One was a PC-based radio system that allows rapid development. The transmit power of this system is low at 25 watts. The PC based system was used in a demonstration jointly supported by ONR and NAVSEA. The radio system demonstrated a throughput of 280kb/s at a range

of 38 miles. This early demonstration provided a number of basic inputs and assessments of modulation schemes, and data formatting which are being utilized. Forward error correction (FEC) is almost universally used for telemetry systems, and this radio system allows rapid implementation of different combinations of FEC and coded modulation schemes. This feature will yield valuable information; the interaction of the combinations of error correction and modulation are not simple to predict in a real channel where noise is frequently non-Gaussian. Further testing has been conducted using a buoy as a surrogate UUV, placing the antenna close to the water, as it will be in operation. Testing indicates that the FLEX antenna configuration will be suitable for data transmission at range.

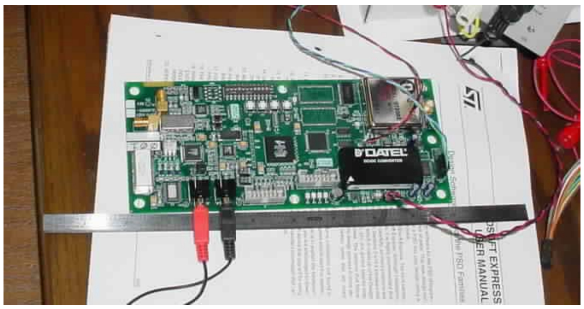

Figure 3. High speed DSP board for compact low power radio with A-D and D-A converters

A small transceiver board has been fabricated which will allow testing of a wide range of modulation types, FSK, PSK, and PAM. The board, shown in Figure 3, is the primary processor, A-D and D-A board for the small radio that will be used in the system shown in Figure 1. This board will have a DSP that will encode and decode the data, and ultimately perform equalization. The transmit power will be variable, from 0.1 to 100 Watts. The total power consumption on receive will be about 5 watts. The power amplifier has about 50 percent efficiency, so maximum power consumption while transmitting will be about 200 Watts. Currently, the first boards for the core analog/digital circuit have been designed, fabricated, and populated. They are being tested and debugged at the hardware level. Software for point-to-point operation is under development. There is an option to add extra-memory for buffering large amounts of data for transmission. Networking can also be supported by this hardware; development of ad hoc networking is currently underway.

Antenna Descriptions. Two antennas have been developed suitable for marine use: a copper wire wound syntactic foam mandrel type shown in Figure 1, and a large gage conductor, freestanding, wire form, collapsible, antenna type shown in Figure 2. The idea behind the syntactic antenna was to provide stable/accurate geometry for the antenna wires while surrounding the wires with a solid dielectric with a value near air, in effect surrounding the antenna with a bubble of “air” to address the wave action issue. Bridging of the antenna legs by drops of water significantly reduces antenna performance. The solid syntactic also allows the antennae and its terminations to resist hydrostatic pressure as well as providing buoyancy. An oil filled syntactic antennae under consideration promises to increase the range of this configuration. Considerable material research and testing was conducted to support this design. The wire form antenna was an effort to reduce antennae cost and to investigate the broadband multi frequency potential of varying the height and pitch of the antenna wires, first seen in a hand wound prototype. The wire form antenna may also be collapsed for portage or stowage. The wire form antenna is more suitable for mass production. The effect of various materials and finish treatments on antenna efficiency is also under investigation.

IMPACT/APPLICATION

Efficient wideband small antennas will make possible long-range point-to-point communication with UUVs. The impact will be to provide comparatively high data rate communications for paths that are ELOS/OTH.

TRANSITIONS

The FLEX antenna is well suited for use with long range autonomous UUVs. ARL:UT is currently conducting an effort to adapt FLEX antennas to UUVs and develop supporting radio systems.

REFERENCES:

[1] J.A. Dobbins, R.L. Rogers, “Folded Conical Helix Antenna,” IEEE Trans. Antennas Propagat, vol. AP-49, No. 12, Dec. 2001, pp. 1777-1781.

[2] R. L. Rogers, J. A. Dobbins, M. A. Koerner, “Clandestine RF Communications for Unmanned Underwater Vehicles,” ONR32, FY99 Annual Reports.

[3] R. L. Rogers, D.P. Buhl, H. Choo, H. Ling “Size Reduction of a Folded Conical Helix Antenna” *IEEE Trans. Antennas Propagat*ion Symposium, June, 2002, San Antonio Texas.